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(54) Abstract Title

Rotor shaft assembly for a gas turbine engine

(57) A rotor shaft assembly for a gas turbine engine 10 includes a downstream turbine shaft 34, an upstream fan shaft 32 and a safety shaft 40. The turbine shaft 34 and the fan shaft 32 are connected by a splined connection (36, figure 1) which allows turbine shaft 34 to drive fan shaft 32. If, during operation, the fan shaft 32 should break, the turbine shaft 34 is brought into driving engagement with the safety shaft 40 via complimentary sets of teeth 60, 62. The driving engagement of the turbine shaft 34 and safety shaft 40 may cause the turbine shaft 34 to break at a weakened region 64 to allow axial movement of the turbine shaft 34, such that a turbine stage (24 figure 1) can come into contact with a fixed structure and prevent an over-speed condition.

Fig.2.

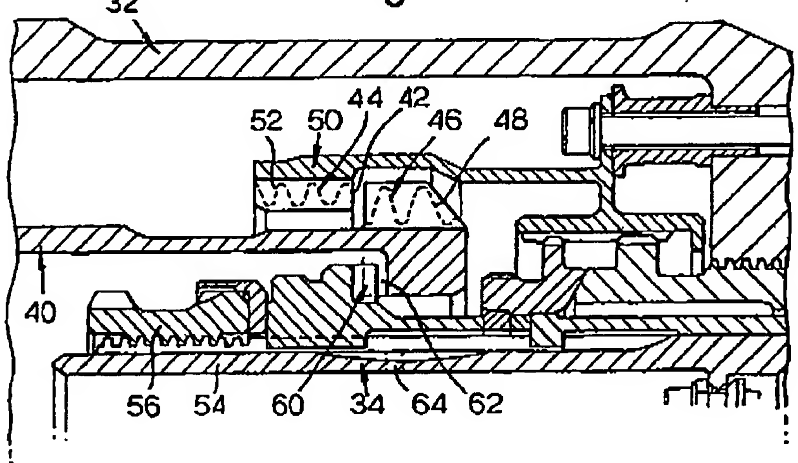

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Fig.1.

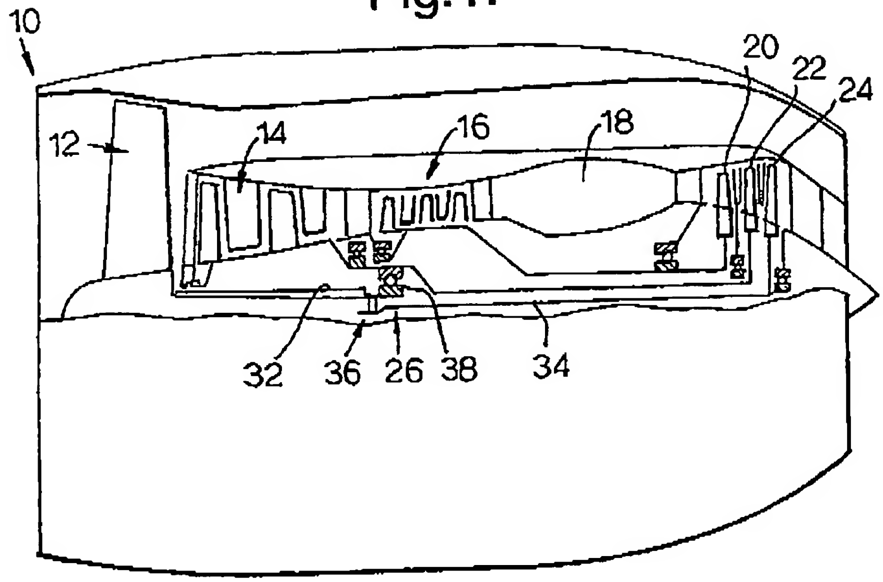
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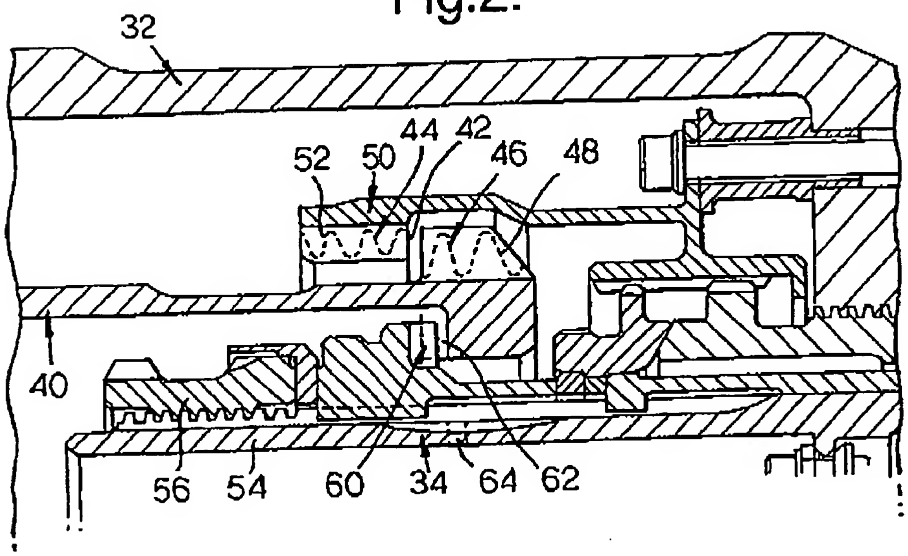
Fig.2.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ROTOR ASSEMBLY FOR GAS TURBINE ENGINE

The present invention relates to a rotor assembly for a gas turbine engine.

Gas turbine engines include one or more turbines driven by combustion gases, each turbine in turn driving a fan or a compressor via an interconnecting shaft. Typically such an engine includes a low pressure (L.P.) turbine, which drives a single stage fan via an interconnecting shaft comprising a fan shaft connected to the fan and a turbine shaft connected to the L.P. turbine, the fan shaft and the turbine shaft being coupled together to allow the L.P. turbine to drive the fan. The engine further includes one or more intermediate/high pressure turbines which drive intermediate/high pressure compressors via respective interconnecting shafts. The engine utilises a thrust bearing structure which is positioned intermediate the shaft ends, for the purpose of locating the L.P. shaft against undesirable axial movement.

Gas turbine engines are commonly used as the propulsion units for aircraft. In the event of an engine breakdown during operation, any damage which results from the breakdown must be minimised so as not to jeopardise the flight capability of the aircraft.

If the fan shaft or L.P. turbine shaft should break and the flow of combustion gases is not stayed, the low pressure turbine will rapidly overspeed because it is no longer driving the fan. The turbine may speed up to 125% of its normal maximum operating speed, with a consequent risk of throwing off its blades.

If the L.P. shaft fails downstream of the thrust bearing structure which provides axial location, the pressures within the engine force the turbine downstream and the turbine blades therefore tangle with a fixed structure such as the outlet guide vanes or exhaust bullet

struts. Therefore the rotational energy of the turbine is absorbed in friction and plastic work, and the turbine overspeed is restrained.

More damaging is if the fan shaft fails upstream of the thrust bearing structure. In this case, the thrust bearing structure prevents axial movement of the downstream portion of the fan shaft or L.P. turbine shaft and prevents tangling. The turbine therefore continues to speed up and complete blades or parts of discs may be thrown off in the radial direction.

In addition to there being a backward force on the turbine in the event of a shaft failure, there is an initial forward force on the fan. This can cause the fan to attempt to move upstream and possibly to be ejected from the engine. In order to prevent this happening, it is known to provide a safety shaft which, in the event of the fan shaft breaking, will arrest upstream movement of the fan and prevent it being ejected from the engine.

According to the invention there is provided a rotor assembly for a gas turbine engine, the rotor assembly including:

a fan stage, a turbine stage and a connection means for drivingly connecting the fan stage and the turbine stage for rotation at a common speed, the connection means including an upstream fan shaft and a downstream turbine shaft coupled together to allow the transmission of torque therebetween; and

a safety shaft connected to the fan stage and extending downstream therefrom;

characterised in including means for bringing the turbine shaft into driving engagement with the safety shaft if the fan shaft breaks, such driving engagement causing the turbine shaft to break under certain engine conditions, the break occurring downstream of the turbine shaft's engagement with the safety shaft.

The terms "upstream" and "downstream" are intended to

refer to the normal direction of movement of gases through the gas turbine engine.

Preferably the turbine shaft is brought into driving engagement with the safety shaft by relative rotational movement therebetween.

The turbine shaft may be brought into driving engagement with the safety shaft on weakening of the fan shaft which allows relative movement of the turbine and safety shafts.

Preferably the turbine shaft and the safety shaft each include sets of teeth, the respective teeth being spaced apart in normal operation but being brought into engagement with one another on relative movement of the turbine and safety shafts, the teeth when in engagement allowing the transmission of torque between the respective shafts.

Preferably the coupling between the fan shaft and the turbine shaft allows relative axial movement therebetween. The turbine shaft may be normally prevented from axial movement by axial location means upstream of the teeth for coupling the turbine shaft to the safety shaft.

Preferably the turbine shaft includes a relatively torsionally weak region located between its coupling with the fan shaft and the teeth for coupling it to the safety shaft, the turbine shaft tending to break in this region when it drives the safety shaft.

Preferably the fan shaft is normally prevented from axial movement by a thrust bearing structure.

A downstream end of the safety shaft may be restrained against axial movement in an upstream direction, by abutment means. Preferably relative rotational movement between the abutment means and the safety shaft is permitted. The abutment means may be attached to the fan shaft.

The abutment means and the downstream end of the safety shaft may each be provided with coarse teeth which may be brought into threaded engagement allowing the end of

the safety shaft to be screwed through the abutment means. Preferably the sense of the screw threads defined by the respective teeth are such that the end of the safety shaft could not screw itself back through the abutment means when being rotated by the turbine, against a slowing or seized fan.

According to the invention, there is further provided a gas turbine engine including a rotor assembly as defined in any of the preceding ten paragraphs.

An embodiment of the invention will be described for the purpose of illustration only with reference to the accompanying drawings in which:

Fig.1 is a diagrammatic view of a known ducted fan gas turbine engine; and

Fig.2 is an enlarged, cross-sectional part view of a ducted fan gas turbine engine incorporating the invention.

Referring to Fig 1, a ducted fan gas turbine engine generally indicated at 10 includes, in axial flow series, a fan 12, an intermediate pressure compressor 14, a high pressure compressor 16, a combustion chamber 18, high pressure turbine stages 20, intermediate pressure turbine stages 22 and low pressure turbine stages 24.

The fan 12 is connected to the low pressure turbine stage 24 by an interconnecting drive shaft 26 which allows for the transmission of rotary drive torque from the turbine stage 24 to the fan 12. Similar intermediate pressure and high pressure drive shafts connect the intermediate and high pressure compressors 14 and 16 with the intermediate and high pressure turbines 22 and 20 respectively.

The gas turbine engine 10 works in the conventional manner so that air entering an air intake is accelerated by the fan 12 to produce two air flows, a first air flow to the intermediate compressor 14 and a second airflow which provides propulsive thrust. The intermediate pressure compressor 14 compresses the air flow directed into it

before delivering the air to the high pressure compressor 16 where further compression takes place.

The compressed air exhausted from the high pressure compressor 16 is directed into the combustion equipment 18 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through and thereby drive the high, intermediate and low pressure turbines 20, 22 and 24 before being exhausted through an exhaust nozzle to provide additional propulsive thrust. The high, intermediate and low pressure turbines 20, 22 and 24 respectively drive the high and intermediate compressors 14 and 16 and the fan 12 by the interconnecting shafts mentioned previously.

The low pressure drive shaft 26 consists of an upstream fan shaft 32, which is attached to the fan 12, and a downstream turbine shaft 34 which is attached to the low pressure turbine 24. The fan shaft 32 and the turbine shaft 34 are connected together in driving engagement by a splined connection 36. The splined connection 36 comprises a helical winding which causes the two shafts to pull together as the turbine shaft 34 drives the fan shaft 32. The shafts 32 and 34 are held against axial movement by a thrust bearing arrangement 38.

If the low pressure drive shaft 26 should break, it will be seen that the low pressure turbine 24 is no longer drivingly connected to the fan 12. The low pressure turbine 24 thus speeds up dramatically and this may cause its blades to be thrown off in a radial direction, thus seriously damaging the engine. As this happens, there is a backwardly directed force on the low pressure turbine. If the low pressure drive shaft 26 breaks in the region of the turbine shaft 34, the turbine 24 is able to move in the downstream direction. This causes it to foul again a fixed structure such as the low pressure guide vanes and causes the rotational energy of the turbine to be absorbed in friction and plastic work, restraining the overspeeed of

the turbine.

If however the low pressure drive shaft 26 breaks in the region of the fan shaft 32, the presence of the thrust bearing 38 prevents downstream movement of the turbine shaft 34. Thus, the low pressure turbine 24 goes into overspeed without moving in the downstream direction and therefore does not foul against any fixed structure. This can be very serious as the turbine blades may be thrown off whole or the turbine discs may burst, causing significant damage to the engine.

In addition, if the low pressure drive shaft 26 breaks in the region of the fan shaft 32, this can have a very detrimental affect on the fan 12 which is initially forced in an upstream direction and may be thrown out of the engine. It is therefore known to provide a safety shaft connecting the fan 12 to some fixed part of the engine, the safety shaft coming into operation if the fan shaft 32 should break.

Fig. 2 illustrates in detail part of a gas turbine engine according to the invention. It may be seen that the engine includes a low pressure drive shaft comprising a fan shaft 32 and a turbine shaft 34 coupled together to allow the transmission of torque therebetween. In normal operation, a low pressure turbine drives a fan via the shafts 32 and 34.

The engine further includes a safety shaft 40 for preventing the fan being thrown forwardly out of the engine in the event of failure of the low pressure fan shaft 32. The safety shaft 40 is attached to the fan 12 and is fixed against significant upstream axial movement by a shoulder 42 of an abutment structure 44.

An annular downstream end 46 of the safety shaft 40 is provided with radially outwardly directed coarse teeth 48 illustrated diagrammatically in Fig. 2. An annular upstream end 50 of the abutment structure 44 is provided with radially inwardly directed coarse teeth 52.

In order to position the safety shaft such that its downstream end 46 is located downstream of the upstream end 50 of the abutment structure, the end 46 of the safety shaft may be effectively screwed through the abutment structure, the coarse teeth enabling the two structures to pass one another when they are rotated relative to one another. However, the sense of the coarse teeth is such that the end 46 of the safety shaft can only be rotated through the abutment structure 44 and past the shoulder 42 by rotation of the safety shaft in a direction in the same sense as to the normal rotation of the fan 12. Thus it may be seen in the event of breaking of the fan shaft 32, the fan 12 slows, but continues to rotate and such rotation initially tends to throw the fan forwards out of the engine. The safety shaft rotates with the fan, the direction of relative rotation between the safety shaft and the abutment structure 44 preventing the teeth from allowing the end 46 of the safety shaft 40 to pass the shoulder 42.

It may be seen in Fig. 2 that the turbine shaft 34 continues in an upstream direction past its coupling with the fan shaft 32. An upstream end 54 of the turbine shaft 34 engages a nut 56 which prevents it from moving in the axial direction during normal operation.

The turbine shaft 34 is provided with a set of radially outwardly directed teeth 60. An annular end of the safety shaft 40 is provided with a complementary set of teeth 62. In normal operation, the respective sets of teeth 60 and 62 do not engage one another, the individual teeth within one set being circumferentially spaced apart from the individual teeth within the set on the other component. Thus, in normal operation there is no driving connection between the low pressure turbine shaft 34 and the safety shaft 40.

In the event of a failure of the low pressure fan shaft 32, the connection between the low pressure turbine

shaft 34 and the fan 12 is lost. Thus, the turbine shaft 34 initially starts to speed up relative to the fan 12, because the turbine shaft 34 is no longer driving the fan 12. The safety shaft 40 is connected to the fan 12 and therefore there is some relative rotation between the turbine shaft 34 and the safety shaft 40. This brings the respective teeth 60 and 62 into driving engagement with on another. Such engagement causes the turbine shaft 34 to drive the fan 12 via the safety shaft 40.

The turbine shaft 34 includes a weakened region 64 located between its splined connection 36 with the fan shaft 32 and its teeth 60. The weakened region 64 is designed such that it tends to break if the low pressure turbine shaft 34 drives the fan 12 via the safety shaft 40, i.e. in the event of the low pressure fan shaft 32 breaking.

If the weakened region 64 of the turbine shaft 34 breaks, this allows the turbine shaft 34 to move in the downstream direction. Therefore, the turbine blades on the low pressure turbine 24 are able to foul against a fixed structure and damage to the engine is minimised.

The above process may take place even before the low pressure fan shaft 32 actually breaks. Such breakage is usually due to overheating and is preceded by a weakening of the fan shaft, this weakening allowing some relative movement of the low pressure turbine shaft 34 and the safety shaft 40 and thus bringing the teeth 60 and 62 into engagement. This causes the turbine shaft 34 to drive the fan 12 and causes the weakened region 64 to break. This can allow the turbine 24 to start to move downstream even before the fan shaft has broken. This causes a much less catastrophic failure.

It may be seen that the safety shaft 40 also functions to prevent the fan 12 from being thrown forwards out of the engine. This is because the coarse teeth 48 and 52 are unable to pass each other when the safety shaft 40 is being

rotated by the fan 12.

If for example the engine is idling, the turbine shaft may not break immediately it is brought into engagement with the safety shaft, because no significant torque is being transmitted. In this case, the low pressure turbine would simply drive the fan 12 via the safety shaft 40 until the next powerful or reverse thrust situation occurred, at which point the turbine shaft would break.

There is thus provided a gas turbine engine in which failure of the fan shaft causes a minimum of damage to the engine.

Various modifications may be made to the above described embodiment without the departing from the scope of the invention. For example, an alternative coupling mechanism between the low pressure turbine shaft and the safety shaft may be used. In addition, an alternative means for preventing the safety shaft from passing the abutment structure in the upstream direction may be used.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

CLAIMS

1. A rotor assembly for gas turbine engine, the rotor assembly including:

a fan stage, a turbine stage and a connection means for drivingly connecting the fan stage and the turbine stage for rotation at a common speed, the connection means including an upstream fan shaft and a downstream turbine shaft coupled together to allow the transmission of torque therebetween; and

a safety shaft connected to the fan stage and extending downstream therefrom;

wherein the rotor assembly includes means for bringing the turbine shaft into driving engagement with the safety shaft if the fan shaft breaks, such driving engagement causing the turbine shaft to break under certain engine conditions, the break occurring downstream of the turbine shaft's engagement with the safety shaft.

2. A rotor assembly according to claim 1, wherein the turbine shaft is brought into driving engagement with the safety shaft by relative rotational movement therebetween.

3. A rotor assembly according to claim 1 or claim 2, wherein the turbine shaft is brought into driving engagement with the safety shaft on weakening of the fan shaft which allows relative movement of the turbine and safety shafts.

4. A rotor assembly according to preceding claim, wherein the turbine shaft and the safety shaft each include sets of teeth, the respective teeth being spaced apart in normal operation but being brought into engagement with one another on relative movement of the turbine and safety shafts, the teeth when in engagement allowing the transmission of torque between the respective shafts.

5. A rotor assembly according to claim 4, wherein the coupling between the fan shaft and the turbine shaft allows

relative axial movement therebetween.

6. A rotor assembly according to claim 4 or claim 5, wherein the turbine shaft is normally prevented from axial movement by axial location means upstream of the teeth for coupling the turbine shaft to the safety shaft.

7. A rotor assembly according to any of claims 4 to 6, wherein the turbine shaft includes a relatively weak region located between its coupling with the fan shaft and the teeth for coupling it to the safety shaft, the turbine shaft tending to break in this region when it drives the safety shaft.

8. A rotor assembly according to any preceding claim, wherein the fan shaft is normally prevented from axial movement by a thrust bearing structure.

9. A rotor assembly according to any preceding claim, wherein a downstream end of the safety shaft is restrained against axial movement in an upstream direction, by abutment means.

10. A rotor assembly according to claim 9, wherein relative rotational movement between the abutment means and the safety shaft is permitted.

11. A rotor assembly according to claim 8 or claim 9, wherein the abutment means are attached to the fan shaft .

12. A rotor assembly according to any of claims 9 to 11, wherein the abutment means and the downstream end of the safety shaft are each provided with coarse teeth which may be brought into threaded engagement allowing the end of the safety shaft to be screwed through the abutment means.

13. A rotor assembly according to claim 12, wherein the sense of the screw threads defined by the respective teeth are such that the end of the safety shaft could not screw itself back through the abutment means when being rotated by the turbine, against a slowing or seized fan.

14. A rotor assembly substantially as herein described with reference to the drawings.

15. A gas turbine engine including a rotor assembly according to any preceding claim.

16. A gas turbine engine substantially herein described with reference to the drawings.

17. Any novel subject matter or combination including novel subject matter disclosed herein, whether or not within the scope of or relating to the same invention as any of the preceding claims.

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INVESTOR IN PEOPLE

Application No:	GB 0117854.0	13	**Examiner:**	Philip Ord
Claims searched:	1-16		**Date of search:**	28 February 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): F1G: GDA, GDB, GDX
F1T: TEA, TEX, TX

Int Cl (Ed.7): F02C: 7/36, 3/107, 3/113
F01D: 5/02, 21/00, 21/02, 21/04, 21/14

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2128686 A	ROLLS-ROYCE- See figures and abstract.	-
A	GB 2114266 A	ROLLS-ROYCE- See figures and abstract.	-
A	GB 2111639 A	ROLLS-ROYCE- See figures and abstract.	-
A	US 4475869	ROLLS-ROYCE- See figures and abstract.	-
A	US 2930189	ROLLS-ROYCE- See figure 1 and column 3 lines 17-46.	-

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.